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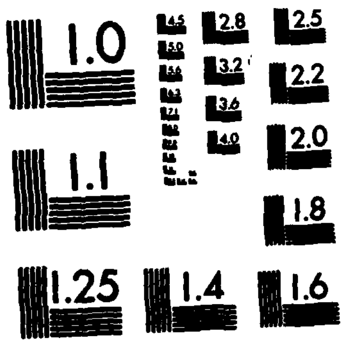

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SYMMETRICAL TELECOMMUNICATIONS CABLE FOR 120-CHANNEL DIGITAL TELEPHONE

by

Tadeusz Lapinski

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SYMMETRICAL TELECOMMUNICATIONS CABLE FOR 120-CHANNEL DIGITAL TELPHONE

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Symmetrical Telecommunications Cable for 120-Channel Digital Telephone

Tadeusz Lapiński

In technologically developed countries digital systems are being broadly introduced. They use time division of channels and pulse-code modulation (PCM). The main advantages in digital telemetric systems are the following: resistance to disturbances originating from crosstalk or internal noise sources, resistance to distortions introduced by the transmission circuit, and low costs. The first digital systems were primary group systems, 24-channel in America, and 30/32-channel in Europe.

Higher group systems are undergoing development in different countries at the present time. In the United States a 96-channel secondary group system has been developed, and in Europe a 120-channel system. The binary bit flow rate for the first is 6,312 Mbit/sec, and for the second system, 8,448 Mbit/sec. One-hundred-Twenty-channel systems have been put to use in France, West Germany, and Italy. In secondary group systems maximum energy density falls in the frequency range 4,224 MHz.

It has turned out that existing symmetrical trunks of cable lines are not suited for installing digital systems with binary flow rates of 8,448 Mbit/sec on them. This obviously has to do with duplex transmission in a single cable. The two transmission directions must be separated by an electrostatic screen. This simple and inexpensive method makes it possible to transmit in a single-cable system. Thus 8,448 Mbit/sec digital systems require special cables which are not too complicated.

The Cable Factory in Ożarów began the production of long-distance telecommunications cable for telemetric digital systems with binary bit flow rates of 8,448 Mbit/sec in 1977. This will make it possible to transmit 120-channel telephone communications. Digital telecommunications cables are specified for the construction of links in intraregional networks, intraprovincial networks, interurban networks, as well as railroad links.

Cable Construction

The production program at the Cable Factory in Ożarów in Masuria includes the following kinds of digital telecommunications cable:

(a) long-distance telecommunications cable, bundle-type, with expanded polyethylene insulation, in aluminum foil and a polyethylene shield -- Type AlTKDNXpx;

(b) long-distance telecommunications cable, bundle-type, expanded polyethylene insulation, in aluminum foil, reinforced with steel bands in a polyethylene shield -- Type AlTKDNXpxFtx;

(c) long-distance telecommunications cable, bundle-type, expanded polyethylene insulation, in aluminum foil, reinforced with round steel wire, in polyethylene shield -- Type AlTKDNXpxFox.

The AlTKDNXpx type cable is specified for laying in cable channels, whereas the AlTKDNXpxFtx and AlTKDNXpxFox type cables are specified for laying directly in the ground over terrain presenting a high degree of threat of mechanical damage (mountainous terrain, river crossings, etc.). All cable types can be laid and installed in ambient temperatures not less than -10°C.

The cable is produced with the following number of pairs: 24, 48, and 84. Upon request of the customer, cable with other numbers of pairs can also be produced.

Every cable section of side-by-side transmission pairs contains the following: one locating pair, one pair for service communications, and three auxiliary pairs.

The cable wires are produced from soft copper wire with a nominal diameter of 0.8 mm. Insulation has been pressed on the wires made of expanded polyethylene with a thickness assuring fulfilling the requirements relating to effective traffic capacity. The wire pairs are twisted into bundles, with each bundle being made up of six pairs wound spirally around a central core made of thermoplastic material (Fig. 1). For the purpose of separating the pairs within the bundle, as

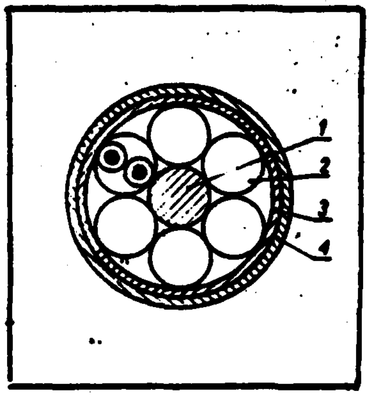

Fig. 1. Six-pair bundle:
1 - core; 2 - pairs; 3 - bundle isolation; 4 - screen.

well as for the purpose of assuring stability to the wires and the bundle, the pairs are covered with a band of colored synthetic thread or a band of thin synthetic foil. The pair covering colors are the following: red - pair 1, blue - pair 2, yellow - pair 3, bronze - pair 4, white - pair 5, and green - pair 6.

The insulated wires are twisted into pairs with appropriately chosen twist lengths guaranteeing good coupling characteristics. The pair wires in the cable are distinguished from each other by means of colored bands deposited on the surface of the colorless insulation. The color of the band on wire a is red, and on wire b it is blue.

Each bundle is wound with synthetic tape with good dielectric properties and with one or several aluminum tapes constituting an electrostatic screen. Under the screen, along the length of the bundle, a grounding wire is placed made of copper-tin wire with a diameter of 0.8 mm.

The bundles made in this way are twisted together in layers to make a core in accordance with Table 1. The cross section of a 48-pair cable core is shown in Fig. 2. The bundles are distinguished among themselves by means of colored coatings made of synthetic thread or synthetic foil.

The locator pair is twisted together from two wires with a diameter of 0.8 mm, insulated with solid polyethylene. The polyethylene insulation of one wire is periodically cut through down to the bare wire at intervals not greater than 100 mm, and the polyethylene insulation of the other wire is solid and has the color red. If the moisture seeps through the cable, as a result of damage to the jacket, there is a reduction in the resistance of the insulation for the locator pair.

Table 1. Construction of digital cable cores and color designations for bundles

No. of pairs	No. of pairs in a bundle	No. of bundles in cable & their make-up	Color of coatings for successive bundles
24	6	4	red, blue, yellow, bronze
48	6	1-7	red + (red, blue, white, green, white, green, white)
84	6	4-10	red, blue, yellow, bronze + (red, blue, green, white, green, white, green, white, green, white)

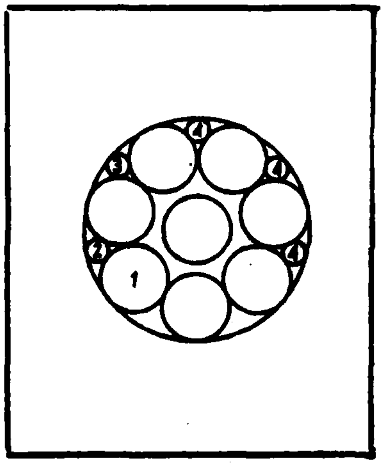

Fig. 2. Cross section of 48-pair cable core: 1 - transmission pairs, 2 - locator pair, 3 - service pair, 4 - auxiliary pairs.

The service pair and auxiliary pairs have the same design as the transmission pairs. These wire pairs are placed in the core between bundles, while in the cores of 48- and 84-pair cables, they are always located on the inside surface staggered in the following manner: locator pair, service pair, auxiliary pairs.

The cable cores are wound with crinkled paper tape, which constitutes the insulation for the core as well as a thermal barrier that protects the wire insulation against damage brought about by elevated temperatures during the welding of the jacket. Next comes an aluminum jacket, rippled, made from aluminum tape laid lengthwise and welded along the seams. The thickness of the aluminum tape, depending on the diameter of the cable core, can be from 0.9 to 1.1 mm.

Because of aluminum's susceptibility to corrosion, jackets made of aluminum are produced with flexible layers of a bituminous blend and a polyethylene shield.

Armored cables have a cushion under the armor in the form of a wrapping of smooth paper tape, crinkled paper tape, or a polypropylene string. The armor deposited on the cushion is made of two steel tapes wound together with a space between them having thicknesses of 0.8 mm, or from a covering made of round steel-tin wire with diameters from 4 to 5 mm depending on the cable diameter. The steel tapes are wound like screwthreads in such a way that the gap or space width between threads for each layer do not exceed 50% the tape thickness, and the top tape covers the gaps between the thread windings of the lower tape. The wires are wound in a screw-like fashion thread by thread. A spiral countercoil made of thin steel tape is wound on the armor made of steel wire, in a direction opposite to the direction of the wound armor wires.

Next, a shield made of high-pressure polyethylene with a carbon black additive having a nominal thickness of 2 mm is pressed onto the cable armor.

All cables bear the producer's stamp, including the letter symbol for the cable, the name of the factory, and the year of production stamped in relief on the cable jacket and clearly legible.

Digital cable is produced in factory sections 500 m long, with the exception of cable with 84 pairs, which have lengths of 250 m. Upon request by the customer, they can be produced in other factory section lengths. The factory cable sections are sealed hermetically on their ends by means of metal caps or by other means assuring a hermetic seal for the cable.

The nominal internal diameters for the cable and minimum bend radii are given in Table 2.

Cable Properties

Maximum resistance values for the wires in the finished cable, measured by means of direct current, at a temperature of 20°C, do not exceed 37 Ω. The unbalance of resistances in wires in pairs for 95% of the pairs does not exceed

Table 2. Internal cable diameters and their bend radii

Cable type	Number of pairs	Internal cable diameter [mm]	Smallest cable bend radius [m]
AlTKDNXpx	24 48 84	47 60.5 76	0.5 0.7 0.9
AlTKDNXpxFtx	24 48 84	58 71 87	0.5 0.7 0.9
AlTKDNXpxFox	24 48 84	62 75 91	0.6 0.7 0.9

1%, and for 100% of the pairs does not exceed 2%. The wire resistances given here refer to cables with the largest cross sections, that is for example, the 84-pair cables. Cables with a smaller number of pairs will have less resistance in the wires. Resistances measured at temperatures other than 20°C can be converted into the value for resistances at a temperature of 20°C according to the following equation:

$$R_{20}=R_t \cdot K,$$

where:

$$K=\frac{1}{1+a(t-20)},$$

t — measurement temperature [°C],

a — thermal resistance factor. For soft copper wire, a=0.00393.

The effective rated capacitance for pairs at frequencies of 800–1000 Hz is 28.5 nF/km. The capacitance unbalance of lines with respect to the ground at frequencies 800–1000 Hz, in factory sections of 500 m length, do not exceed 1000 pF, and in 250 m lengths, do not exceed 500 pF.

The line wave impedance at a frequency of 120 kHz is 165 ± 10 Ω.

The wave attenuation constant for these lines at frequencies of 4.2 MHz at

a temperature of 10°C is 14.1 ± 0.4 dB/km. The graph of the wave attenuation constant as a function of frequency at a temperature of 10°C is shown in Fig. 3.

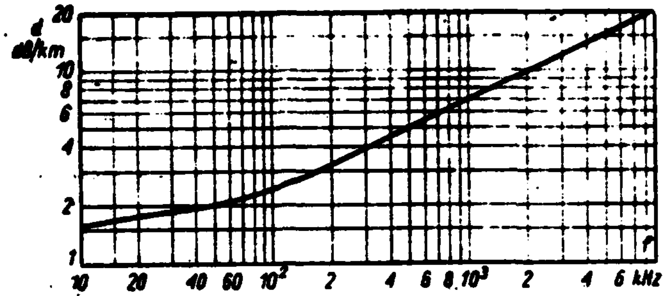

Fig. 3. Wave attenuation for transport lines as a function of frequency.

Near-end crosstalk loss at a frequency of 4.2 MHz, which is equivalent to the mean energy of near-end crosstalk between the pairs of different bundles, is at the least 130 dB in a factory section not less than 250 m long. This requirement is met in the frequency band 4.2 to 8.5 MHz.

The far-end crosstalk level at a frequency of 4.2 MHz, which is equivalent to the mean energy of far-end crosstalk between the pairs of any arbitrary bundle, is at the least 50 dB in a factory section 500 m long, and in a section 250 m long, at the least 53 dB.

The wire insulation will bear without breakdown, for a period of 1 minute, an AC test voltage with a frequency of 50 Hz and a magnitude of 1000 V, or a DC voltage with a magnitude of 1.5 kV, applied between all a wires connected with each other and all b wires connected with each other. One of the groups is connected with the screen, the metal jacket, and the ground. The insulation between all wires connected together and connected with the metal jacket including the screen will hold up without breakdown, for a period of 1 minute, an AC test voltage with a frequency of 50 Hz and an effective magnitude of 2000 V, or a DC voltage equal to 3000 V.

The insulation resistance for each wire in the finished, manufactured cable, in relation to a 1 km length, amounts to at least 10,000 MΩ with respect to the remaining wires connected among themselves and with the screen.

Th insula[illegible]g materials between the wires of the locator pair and between

the screen and metal jacket bear without breakdown, for a period of 1 minute, a 500 V DC test voltage. The resistance of the locator pair insulation for 60% of the factory sections amounts to at least 5000 MΩ·km, and for 100% of factory sections, at least 2000 MΩ·km.

The wire resistances, insulation resistances, and capacitance unbalance with respect to the ground of the service pair and the auxiliary pairs are the same as for the transmission pairs. The insulation between the service pair wires and the auxiliary pair wires and between the screen and the metal jacket bears without breakdown, for a period of 1 minute, an AC test voltage with a frequency of 50 Hz and an effective magnitude of 500 V, or a 750 V DC voltage. The wave impedance for the service line and the auxiliary lines amounts to 500-1490 Ω. The graph of the wave impedance constant for the service line and auxiliary lines at a temperature of 10°C and as a function of frequency is shown in Table 3.

Table 3. Wave attenuation of service link and auxiliary links.

f	[kHz]	0.3	0.6	0.8	1.0	2.0	3.0	3.4
a	[dB/km]	0.38	0.54	0.61	0.71	0.93	1.09	1.15

Line cables are introduced into central exchanges by means of single-bundle digital transmission cables with six or five pairs. Five-pair cable has pairs for auxiliary services.